CLAIMS

1. A method of estimating a joint moment of a bipedal walking body, comprising: a first step for sequentially grasping the displacement amounts of a plurality of joints, including at least an ankle joint, a hip joint and a knee joint of each leg of a bipedal walking body;

a second step for sequentially grasping the positions and/or postures of corresponding rigid bodies of the bipedal walking body that are associated with rigid elements of a rigid link model using at least the rigid link model, the rigid link model being established beforehand to express the bipedal walking body in the form of a link assembly composed of a plurality of the rigid elements and a plurality of joint elements and the grasped displacement amounts of the joints;

a third step for grasping the acceleration of a preset reference point of the bipedal walking body by using at least an output of an acceleration sensor attached to a predetermined region of the bipedal walking body; and

a fourth step for sequentially grasping a floor reaction force acting on each leg and the position of an acting point of the floor reaction force, the grasped positions and/or the postures of the corresponding rigid bodies of the bipedal walking body, the acceleration of the reference point, the floor reaction force, and the

position of the acting point of the floor reaction force being used to estimate a joint moment acting on at least one joint of each leg,

wherein at least the displacement amounts of the hip joint, the knee joint, and the ankle joint of each leg that are grasped in the first step include the amount of rotation about an axis substantially perpendicular to a leg plane as a plane passing through these three joints, the displacement amount of the hip joint is a three-dimensional amount, the positions and/or postures of the corresponding rigid bodies grasped in the second step include at least the positions and/or the postures of the corresponding rigid bodies of the leg on the leg plane, the acceleration of the reference point grasped in the third step and the floor reaction force and the position of the acting point of the floor reaction force grasped in the fourth step are three-dimensional amounts, and

a component of a joint moment acting on at least one joint of the leg about the axis that is substantially perpendicular to the leg plane is estimated on the basis of an inverse dynamic model representing the relationship between the motions of the corresponding rigid bodies of the leg and the translational forces and the moments acting on the corresponding rigid bodies on the leg plane by using the two-dimensional amounts obtained by projecting at least the acceleration of the reference point, the floor reaction force, and the position of the

acting point of the floor reaction force onto a leg plane related to the leg on the basis of a displacement amount of the hip joint of the leg, and the positions and/or the postures of the corresponding rigid bodies of the leg on the leg plane.

2. The method of estimating a joint moment of a bipedal walking body according to Claim 1, wherein the acceleration of the reference point grasped in the third step, and the floor reaction force and the position of the acting point of the floor reaction force grasped in the fourth step are three-dimensional amounts expressed in terms of a body coordinate system set beforehand as a three-dimensional coordinate system fixed to one predetermined rigid element of the rigid link model.

3. The method of estimating a joint moment of a bipedal walking body according to Claim 2, comprising:

a fifth step for sequentially determining the position of the overall center-of-gravity of the bipedal walking body in the body coordinate system by using the displacement amounts of joints of the bipedal walking body grasped in the first step and by using the rigid link model,

a sixth step for sequentially determining the acceleration of the overall center-of-gravity in the body coordinate system from the time series data of the position of the overall center-of-gravity and the acceleration of the origin of the body coordinate system

grasped using at least an output of the acceleration sensor, and

a seventh step for sequentially determining whether a motion state of the bipedal walking body is a one-leg supporting state in which only one of a pair of legs is in contact with the ground or a two-leg supporting state in which both legs are in contact with the ground,

wherein, if the motion state of the bipedal walking body is the one-leg supporting state, then the fourth step estimates the value of a floor reaction force in the body coordinate system according to a dynamic equation of the overall center-of-gravity of the bipedal walking body expressed by the acceleration of the overall center-of-gravity determined in the sixth step, the total weight of the bipedal walking body, and the floor reaction force acting on the leg in contact with the ground; and if the motion state of the bipedal walking body is the two-leg supporting state, then the fourth step grasps the values of the floor reaction forces acting on the two legs, respectively, in the body coordinate system, on the basis of a dynamic equation of the overall center-of-gravity of the bipedal walking body expressed by the acceleration of the overall center-of-gravity determined in the sixth step, the total weight of the bipedal walking body, and the floor reaction force acting on the two legs, respectively, and an expression of the relationship between the relative position of a specific part of the leg with respect to the

overall center-of-gravity of the bipedal walking body and a floor reaction force acting on the leg, which is established on the assumption that the floor reaction forces acting on the legs are the vectors acting toward the overall center-of-gravity of the bipedal walking body from the specific part specified beforehand in the vicinity of the bottom end of the leg.

4. The method of estimating a joint moment of a bipedal walking body according to Claim 1, comprising:

an eighth step for sequentially grasping the inclination angle, relative to the vertical direction, of a corresponding rigid body of a bipedal walking body, which corresponds to one predetermined rigid element of the rigid link model,

a ninth step for determining whether each of the legs of the bipedal walking body is in contact with the ground, and

a tenth step for grasping the positional relationship among at least the overall center-of-gravity of the bipedal walking body, the ankle joint of each leg in contact with the ground, and the metatarsophalangeal joint of the foot portion of the leg, and the vertical position of the ankle joint by using the inclination angle grasped in the eighth step, a displacement amount of each joint of the bipedal walking body grasped in the first step, and the rigid link model,

wherein the fourth step estimates the position in a

horizontal plane of the acting point of a floor reaction force acting on a leg on the basis of the positional relationship among the overall center-of-gravity, the ankle joint of each leg in contact with the ground and the metatarsophalangeal joint of the foot portion of the leg grasped in the tenth step, and also estimates the vertical position of the acting point of a floor reaction force acting on the leg on the basis of the vertical position of the ankle joint of the leg.

5. The method of estimating a joint moment of a bipedal walking body according to Claim 4, wherein, if the overall center-of-gravity exists at the rear side of the bipedal walking body in the forward/backward direction with respect to the ankle joint of the leg in contact with the ground, then the fourth step estimates the position in the horizontal plane of the ankle joint of the leg as the position in the horizontal plane of the acting point of the floor reaction force acting on the leg, if the overall center-of-gravity exists at the front side of the bipedal walking body in the forward/backward direction with respect to the metatarsophalangeal joint of the foot portion of the leg in contact with the ground, then the fourth step estimates the position in the horizontal plane of the metatarsophalangeal joint of the foot portion of the leg as the position in the horizontal plane of the acting point of the floor reaction force vector acting on the leg, and if the overall center-of-gravity exists at

the front side of the bipedal walking body in the longitudinal direction with respect to the ankle joint of the leg in contact with the ground and exists at the rear side with respect to the metatarsophalangeal joint of the foot portion of the leg, then the fourth step estimates the position of a point in the horizontal plane at which its longitudinal position agrees with the overall center-of-gravity position on a segment that connects the ankle joint and the metatarsophalangeal joint of the leg, as the position in the horizontal plane of the acting point of the floor reaction force acting on the leg.

6. The method of estimating a joint moment of a bipedal walking body according to Claim 4, wherein the fourth step estimates the vertical position of the acting point of a floor reaction force acting on a leg in contact with the ground as the position away downward in the vertical direction by a predetermined value, which has been specified beforehand, from the vertical position of the ankle joint of the leg grasped in the tenth step.

7. The method of estimating a joint moment of a bipedal walking body according to Claim 6, wherein whether each of a portion adjacent to a toe side and a portion adjacent to a heel side of a foot portion of a leg, which has been determined to be in contact with the ground, is in contact with the ground is determined in the ninth step, the vertical position of the ankle joint of the leg in contact with the ground and the vertical position of the

metatarsophalangeal joint of the foot portion of the leg are grasped in the tenth step, and the fourth step estimates the vertical position of the acting point of the floor reaction force by using a vertical distance between the ankle joint and the metatarsophalangeal joint determined from the vertical position of the ankle joint and the vertical position of the metatarsophalangeal joint, which have been grasped in the tenth step, in place of the predetermined value if it is determined in the ninth step that only the portion adjacent to the toe side out of the portion adjacent to the toe side and the portion adjacent to the heel side of the foot portion is in contact with the ground.